

N 91 - 25984

FROM C/MRKOS TO P/HALLEY : 30 YEARS OF
COMETARY SPECTROSCOPY

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An **Atlas of Cometary Spectra** has been compiled, as a sequel to the well-known **Atlas** published by Swings and Haser in 1956. The new **atlas** comprises some 400 reproductions of cometary spectra secured in the world's largest observatories during the three decades or so from the passage of comet Mrkos 1957 V, for which the very first high-dispersion spectrum was obtained, to the return of Halley's comet. The illustrations refer to 40 different comet apparitions; they are grouped into a set of 186 loose 11" x 14" plates, while the texts, comments and relevant data are given in a separate booklet.

The main purpose of this **atlas** is to show in detail the tremendous progress which was achieved in cometary spectroscopy during the period covered, essentially thanks to the use of high-resolution coudé spectrographs and large telescopes, the considerable extension of the observed wavelength range, and the advent of electronic detectors. It is divided in two parts. Part I, which contains about two thirds of the selected material, presents photographic spectra, while electronically recorded spectra covering the vacuum ultraviolet, through the optical, infrared and radio regions appear in Part II.

The table of contents as well as reproductions of a few **atlas** plates are shown in the display.

ROSETTA, the Comet Nucleus Sample Return Mission

by

A. ATZEI (ESA) - R. MITCHELL (JPL)

Rosetta is a cornerstone mission of the science programme of the European Space Agency (ESA) and it is being studied as a collaborative project with NASA. Since 1986, ESA and NASA have been jointly defining the science objectives and conducting mission design and engineering studies. ESA is also developing most of the new technologies required by the mission.

The major scientific objective of Rosetta is to return cometary nucleus samples to earth, while preserving their fundamental chemical, isotopic and structural properties. Rosetta will provide information important to planetary scientists, astrophysicists and life scientists. It will investigate the nature of the raw material of the solar system (interstellar dust and organic compounds) and address the presolar processes in stars and the interstellar medium that created this raw material. The analysis of the most primitive condensed organic material could establish an essential link with the prebiotic environment that preceded the beginning of life.

The proposed mission is based on a Titan/Centaur launcher and on a spacecraft assembly of three modules: a cruiser, a lander and an earth re-entry capsule. The cruiser is in charge of the overall mission control; the lander contains anchoring, sampling, and manipulation mechanisms; the earth re-entry capsule is in charge of preserving the samples until their recovery on earth. The mission will be controlled via the DSN.

The spacecraft would be launched in December 2002 into a delta vega trajectory; in January 2008, it will approach a short period comet (Hartley-2 is the current target) near its aphelion, at about 5 AU. It will spend about 100 days in near-comet orbits, performing a global comet characterisation and detailed mapping of suitable landing sites by means of active and passive optical and microwave instruments. It will eventually synchronize its motion with that of a selected landing site and initiate an autonomous slow vertical descent using laser mapping techniques for position control. After touch down, it will perform sounding to identify the subsurface properties of the sampling site. It will then anchor to the nucleus by means of penetrating devices fired into the soil, for compensating torques and forces generated during sampling in a milligravity environment. Sampling operations will begin with the deployment of a container attached to a robot arm, to collect and compress pieces of loose material from the cometary surface. Subsequently, a drill facility will collect core samples 1 to 3 meters from below the surface in 4 cylindrical 60 cm long and 10 cm diameter pieces. A manipulator arm will store the samples inside the aerocapsule in a super isolated container, in which a hermetically sealed compartment will prevent loss of the volatile components preserved in the deepest core sample. Inside this container, the samples will be kept around 130 K until recovery. The sampling operations, which may last up to 15 days, will be autonomous to a great extent and will be performed according to pre-determined sequences loaded on board and adjustable as function of the local soil properties. Once the sampling operations are completed, the cruiser and the aerocapsule will re-launch toward Earth, leaving the lander behind. Two years later, in November 2010, while the spacecraft approaches Earth, the aerocapsule will separate from the cruiser, and it will accomplish a ballistic atmospheric re-entry. After a parachute assisted final descent, the aerocapsule will touch-down on the Pacific Ocean, where it will be recovered by ship-based helicopters and the sample container delivered to the receiving laboratory.

FRAGMENTATION AND DENSITY OF METEOROIDS; P.B.Babadzhanov
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Photographic observations of meteors carried out in Dushanbe by the method of instantaneous exposure (0.00056 s) have shown clearly that meteoroids entering the Earth's Atmosphere are subjected to different types of fragmentation (Babadzhanov 1983) The main forms of fragmentation are:

- 1) the decay of a meteoroid into comparable large nonfragmenting debris;
- 2) the progressive disintegration of the original meteoroid into fragments, at which each fragment continue to disintegrate into smaller fragments;
- 3) the quasi-continuous fragmentation - a gradual release of smallest fragments from the surface of a parent meteoroid and their subsequent evaporation;
- 4) the instantaneous spray of a large number of small particles that gives rise to flares on meteor light curve.

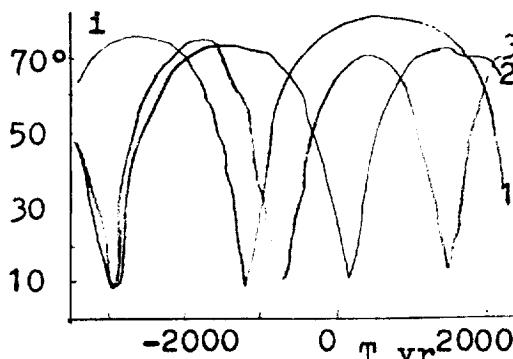
Observations show that the quasi-continuous fragmentation of meteoroids is mostly spread. Using the physical theory of meteors which takes into account the quasi-continuous fragmentation based on light curves of meteors both the density of meteoroids of different streams and the sizes of separated fragments have been determined. The results enable to conclude that the densities of meteoroids are of over magnitude higher than they had been assumed before. Moreover they are close to the densities of carbonaceous and ordinary chondrites.

REFERENCE:

Babadzhanov P.B. 1983, in Asteroids, Comets, Meteors, eds. C.I. Lagerkvist and H.Rickman, Reprocentralen HSC, Uppsala, pp;439-445

P/MACHHOLZ 1986 VII AND QUADRANTID METEOROID STREAM. ORBITAL EVOLUTION AND INTERRELATION; P.B.Babadzhanov, Yu.V.Obrubov, Institute of Astrophysics, Dushanbe, 734670 USSR

The Quadrantids are the most interesting major meteor shower. However, a search for the hypothetical parent comet has been unsuccessful since long. In 1986 D.Machholz discovered a comet, which would have been a progenitor for the Quadrantids, in spite of a significant difference between the present comet's orbit and the observed orbits of the Quadrantids (B.McIntosh, 1990, Icarus, 86, p.299). The investigations of the P/Machholz and the Quadrantids orbital evolution show the similarity in their dynamical behavior although a certain shift in time. This shift is obvious from Fig., which presents the evolution of orbital inclinations i of the P/Machholz comet (curve 1) and a modelled Quadrantid meteoroid (curve 2). However, due to the closeness to



the Jupiter's orbit the period of variation of i depends strongly on the initial position of a body in its orbit. Moreover, in long time intervals the element determining the body's position in the Keplerian orbit is calculated rather roughly. Thus, it is necessary to study the motion of the comet or a meteoroid under different starting positions. Curve 3 in Fig. denotes the variation in orbital inclination of a modelled Quadrantid meteoroid, that coincides in phase with variation of P/Machholz up to 500 A.D. It is necessary to note that curves 2 and 3 were obtained for the meteoroids of the same initial orbit, although their starting positions differed by 180°. Thus, it is evident that the observed difference between the orbits of the P/Machholz comet and the Quadrantid meteor shower may be resulted from the planetary perturbations.

Six of eight near-earth or earth-crossing orbits of the P/Machholz comet are given below. These orbits are the theoretical (T) orbits of possible meteor showers of the P/Machholz. Here also given the observed (O) mean orbits of the meteor showers which can be produced by the same meteoroid stream (P.B. & Yu.O., 1989, Highlights of Astron., v.8, p.287).

Quadrantids					Ursids				
e	q	i	Ω	w	e	q	i	Ω	w
T 0.746	0.78	74°	280°	171°	T 0.758	0.73	73°	278°	189°
O 0.682	0.97	70	282	168	O 0.761	0.97	63	281	195
S. δ-Aquarids					N. δ-Aquarids				
T 0.985	0.05	22	130	327	T 0.989	0.03	19	312	147
O 0.970	0.07	23	154	307	O 0.960	0.08	21	331	128
Daytime Arietids					δ-Cetids				
T 0.988	0.04	23	71	32	T 0.985	0.05	19	248	213
O 0.0940	0.09	21	77	29	O 0.950	0.06	20	258	202

So, a satisfactory similarity of the theoretical and observed meteor shower orbits points to the fact that these showers could have been resulted from the decay of P/Machholz nuclear.

RADAR METEOR ORBITAL STRUCTURE OF SOUTHERN HEMISPHERE COMETARY DUST STREAMS; W.J. Baggaley, A.D. Taylor, Physics Department, University of Canterbury, Christchurch, New Zealand.

The Christchurch, New Zealand meteor orbit radar (AMOR) with its high precision and sensitivity, permits studies of the orbital fine structure of cometary streams. PC generated graphics will be presented of data on Southern Hemisphere Streams. Such structure can be related to the formation phase and subsequent dynamical processes of dust streams.

A SOUTHERN HEMISPHERE RADAR METEOR ORBIT SURVEY;
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A meteor radar system has been operating on a routine basis in Christchurch, New Zealand, to determine the orbits of earth-impacting solar system dust particles. The system sensitivity is +13 visual magnitude corresponding to 100 micron size particles. With an orbital precision of 2° in angular elements and 10% in $1/a$, the operation yields an average 1500 orbits daily with $> 10^5$ to date.

The use of PC's and automated data reduction permit large data sets to be routinely reduced.

Illustrative examples will be presented using comprehensive graphics of the signal processing and orbit reduction. Current studies include the solar system dust orbital distribution; the influx of dust associated with NEA's and the orbital structure existing in cometary streams.

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Diffusion of gas through porous dust layers formed in comet simulation experiments (KOSI)

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The thermodynamic behaviour of cometary nuclei is difficult to determine in situ. In the comet simulation experiments (KOSI) conducted at the space simulator at DLR in Köln, Germany, a sample of some tens of cm composed of porous ices of H_2O and CO_2 , minerals and carbon simulating the comet nucleus is irradiated by an artificial sun.

The temperatures and the pressures within the samples are measured in various depths. The pressure within porous cometary nuclei plays an important role in heat conduction via the gas phase into the nucleus, in gas and in dust emission mechanisms. Two processes are responsible for the actual value of the pressure. The first is gas sublimation and recondensation controlled by the amount of heat conducted into the nucleus. The second is diffusion of the gases through the porous texture of the sample. After some hours of irradiation a dust mantle builds up on the sample surface. The diffusion constant of such porous dust layers have been studied in detail.

The measurement of the diffusion constant was performed by directing a constant flow of N_2 gas through a sample of known size and measuring the pressure differentials between both sides with capacitive pressure gauges. The diffusion constant was found to vary between 1 and $3 \cdot 10^{-3} \text{ m}^2/\text{s}$ with different species of dust.

ON THE VALIDITY OF MARKOV CHAIN METHODS FOR MODELLING OF ORBITAL EVOLUTION.

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Studies of the origin and evolution of comets or asteroids require the exact solution of their long term dynamical evolution. Such a solution is still computationally unattainable for a statistically significant number of small bodies. Therefore, these diffusions are frequently approximated by Monte Carlo methods. Essentially, these methods replace the exact diffusion mapping by a stochastic Monte Carlo mapping. A further efficient simplification involves representing the diffusion by a probability matrix, itself a by-product of the Monte Carlo method. This is the Markov chain formalism from which the asymptotic behaviour is readily extracted. We know of three such applications to cometary and asteroid dynamics. Here we present an independent test of the Markov method where we assert its efficiency and reliability using a discrete dynamical system (a mapping), as in our previous test of the Monte Carlo method.

**SOME EXPERIMENTS RELEVANT TO THE FORMATION OF A
COMETARY ORGANIC CRUST**; G.A.Baratta, Osservatorio Astrofisico di
Catania; G.Strazzulla, Istituto di Astronomia di Catania

For several years many experimental results have been obtained on the chemical and physical changes induced by ion and electron irradiation of materials with a view to their Astrophysical relevance¹⁻⁴. Among the studied effects one of particular interest is the formation of an organic refractory residue left over after ion irradiation and warming-up at room temperature; we call this residue IPHAC (Ion Produced Hydrogenated Amorphous Carbon). Although "in situ" infrared spectroscopy has pointed out both the formation of new molecular species during irradiation, as well as the presence of features even observed in the organic residue at room temperature, it is not clear if IPHAC is already formed or if its formation is triggered by temperature increase during warming-up of the irradiated target.

Being Raman spectroscopy a technique particularly suitable in providing valuable evidence to the structural properties of carbonaceous material⁵, we have thought and build up an experimental apparatus to obtain Raman Spectra of frozen Hydrocarbons during ion irradiation⁶. The present experimental results point out to the formation of IPHAC already at low T (10K) during ion irradiation.

These results may have relevant astrophysical applications, in particular for cometary physics, indeed they support the hypothesis that the cometary organic crust can be already formed during the long stay (4.6×10^9 years) in the Oort cloud and its development does not require a first passage (heating) in the inner Solar System.

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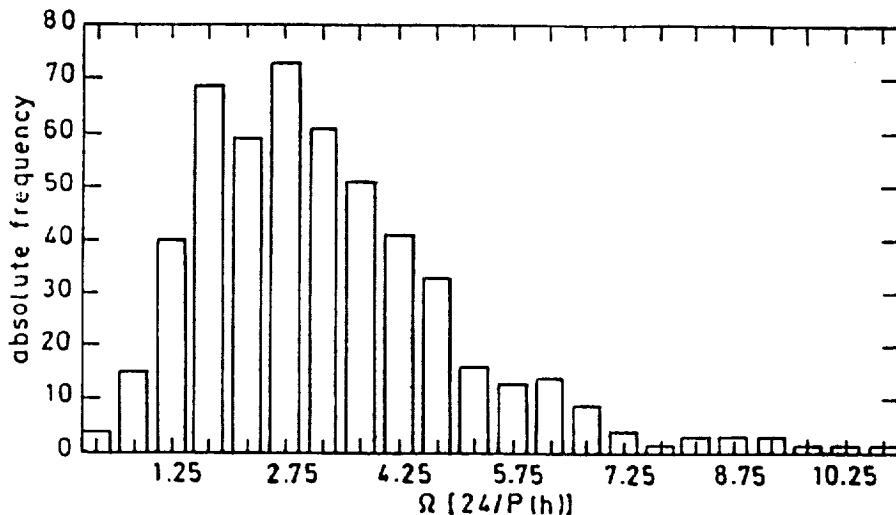
Comets Formation and their Contribution to the Volatiles on the Terrestrial Planets

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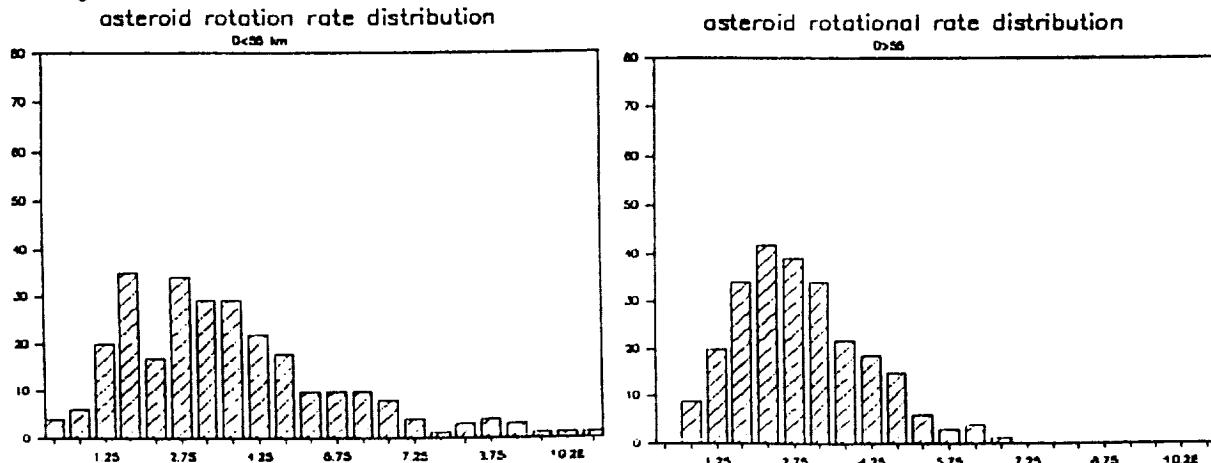
NO ABSTRACT AVAILABLE

DOES EXIST A "NATURAL BREAK" IN THE SPIN DISTRIBUTION OF SMALL ASTEROIDS? A. Barucci, Observatoire de Paris; M. Di Martino, Osservatorio Astronomico di Torino; and M. Fulchignoni, Istituto Astronomico, Universita' La Sapienza, Roma.

The spin rate distribution of more than 500 asteroids (shown here below), having reliability codes larger than 2, have been examined.



A gap corresponding to 2 rev./day is evident. The gap is enhanced in all the subsamples of objects with diameter lesser or equal to 55 km and disappears in the subsample of objects with diameter larger than 55 km.



Binzel (1984, Icarus 57, 294) found in his sample of asteroids with diameter less or equal 30 km the same gap, and he refers to it as "a natural break" in the spin distribution. This gap is not due to selection effects in the determination of the rotational period or in the graphical representation.

We discuss the possible meaning of this confirmed "natural break" in terms of collisional evolution of the asteroid population.

THE NATURE OF 951 GASPRA A. Barucci, Observatoire de Paris; M. Coradini, ESA Hdq, Paris; M. Di Martino, Osservatorio Astronomico di Torino; M. Fulchignoni, C. De Sanctis and A. Rotundi, Istituto Astronomico, Universita' La Sapienza, Roma.

The Galileo spacecraft will fly-by the asteroid 951 Gaspra on October 29, 1991. The results of an international observation campaign carried out in the past years have been utilized to precalibrate and define the sequence of observations by the Galileo Spacecraft Instruments. This will be the first close approach of an asteroid by a man-made spacecraft. 951 Gaspra will be observed by several instruments that will provide us with a unique set of measurements. The information obtained during the Galileo fly-by, besides their intrinsic value, will represent a formidable "ground-truth" to calibrate the methods developed to infer asteroid properties out of ground based observations.

In May 22, 1991 the last opposition before the encounter will occur. We obtained observing time at the ESO (La Silla) 2.2 meter telescope (April, June, July, August) to perform CCD photometry and observing time at 1 meter telescope (May and June) IR + photoelectric photometry. We will report on the preliminary results obtained during the above mentioned campaign. Our aim is to refine and/or determine with the best possible accuracy the asteroid pole orientation, phase function, shape and morphology. We are confident will come up with a sound model of 951 Gaspra before Galileo spacecraft will encounter it.

ON THE POSSIBILITY OF DETERMINING THE MASS OF SOME MINOR PLANETS OF THE HIPPARCOS PROGRAMME; A. Bec-Borsenberger, Service des calculs et de Mécanique céleste du Bureau des Longitudes, Unité Associée au CNRS 00707, 77 avenue Denfert-Rochereau, F-75014 Paris, France

A systematic study of the close approaches of the minor planets of the Hipparcos programme is carried out, mainly during the periods of the observations realised for and by the satellite Hipparcos, in order to determine, when this is possible, the mass of the minor planets concerned.

DETERMINATION OF METEOR FLUX DENSITY DISTRIBUTION OVER THE CELESTIAL SPHERE. O.I.BELKOVICH, Engelhardt Astronomical Observatory, T.K.FILIMO-NOVA, V.V.SIDOROV, Kazan University.

A new method of determination of meteor flux density distribution over the celestial sphere from observations by radar with measurements of arrival angles of radio waves reflected from meteor trails is discussed. The rôle of small meteor showers over the sporadic background is shown.

THE S-TYPE ASTEROID CONTROVERSY. Jeffrey F. Bell (Dept. of Geology and Geophysics, SOEST, Univ. of Hawaii, Honolulu HI 96822)

The longest running argument in asteroid science concerns the mineral composition and meteoritical association of the asteroids assigned to taxonomic type S. The approaching flyby of the S-type asteroid Gaspra by the Galileo spacecraft will drag an even larger section of the space science community into this turgid debate. Below are summarized the various proposed S asteroid surface compositions in roughly the order in which they appeared.

A) ORDINARY CHONDRITES: It was known long before asteroid spectroscopy began that ordinary chondrites (OCs) make up more than 75% of observed meteorite falls. Thus when the first asteroid colors and albedos were obtained in the early 1970s there was a strong expectation that many asteroids would resemble OCs. Indeed, the spectral class "S" originally was intended to stand for "silicaceous" as "M=metal" and "C=carbonaceous". Thus the original 3 asteroid types neatly accounted for ordinary chondrites, irons, and carbonaceous chondrites.

B) STONY-IRONS: Later, when spectra of ordinary chondrites were measured in the lab it became apparent that they actually had little similarity to S asteroids. The asteroids have a steep red continuum totally unlike that of the OCs, and the details of the silicate bands vary wildly, implying mineralogies usually far outside the OC range. To explain these facts it was suggested that most S-type surfaces are differentiated assemblages of metal, orthopyroxene, and olivine, similar to stony-iron meteorites.

C) WEATHERED ORDINARY CHONDRITES: Upon discovery of the continuum slope problem, advocates of interpretation A) proposed that the red continuum of S asteroids is created by some "space weathering" process which alters the spectrum of the uppermost regolith. This proposal has inspired investigations of both synthetic metal-rich regoliths derived from OCs and natural OC parent body regolith material preserved in some meteorite breccias. All these studies demonstrate that "weathered" OC material does not redden, but rather becomes spectrally flatter and in extreme cases approximates a C-type spectrum, never an S-type.

D) CARBONLESS CARBONACEOUS CHONDRITES: When the first near-IR spectra of S asteroids revealed that most had higher ol/pyx than any OC, it was proposed that they represented unknown types of chondrites, specifically material with the silicate composition of carbonaceous chondrites but no carbon. But since no such meteorites have ever fallen on Earth, this hypothesis requires its advocates to abandon the very fall-statistics argument that had originally inspired the chondritic interpretation of S-types in the first place. Furthermore, the asteroid Flora which was cited as the most OC-like of the S-types was later shown to have large variations in silicate mineralogy between different regions of its surface, far outside the range of OCs.

E) EVERYTHING: The mounting spectral evidence for wild variations in composition between different S asteroids and even across the surface of individual ones leads some workers to wonder if both schools might be right. It is impossible to rule out some chondritic areas on the surfaces of S asteroids with the current data, if one allows the other areas to be made of extreme differentiated mineralogies (e.g. pure metal or pure olivine). Since we observe an entire "hemisphere" at once with Earth-based telescopes the chondritic areas could not be separated from the differentiated areas. The fatal objection to this theory is that the actual OC breccias do not contain differentiated clasts, which would be sure to exist in the regolith of a "patchwork asteroid".

F) NOTHING: Alternatively one may take the wide variety of S spectra to indicate that there is really no such thing as a unified "S-type asteroid", but a variety of different objects with different origins and histories which we have not yet properly distinguished. For instance, the Eos asteroid family contains objects formally classified S in most systems, but with IR spectra that closely match those of CO or CV chondrites. A new class "K" was recently created to contain these objects. But there does seem to be a hard core of well observed objects with classical S properties that will always remain even if some of the fainter objects which have only incomplete spectral data later turn out to be something else.

THE CURRENT POSITION: At present almost all scientists actively involved in research on asteroid composition appear to hold some version of interpretation B. In fact, no full journal article defending any other view has appeared for at least 10 years. Yet some of them (especially C) continue to be defended vigorously in less formal situations, and none can be rigorously excluded on the basis of current data.

ASTEROIDS WITH UNUSUAL LIGHTCURVES: 14 IRENE AND 51 NEMAU-SA; I.N.Belakaya, Astronomical Observatory of Kharkov University, and A.N.Dovgopol, Main Astronomical Observatory of the Ukraine Academy of Sciences, Kiev, USSR

New photometric observations of 14 Irene and 51 Nemaua received in 1989 and 1990 are presented. Irene's rotation period of 28.06 hours which three times longer than previously reported is the most suitable to our observations. Composite lightcurves of both asteroids display very irregular shape with at least three pairs of extrema. We applied different methods including Fourier analysis and numerical modelling to interpret all available data of these asteroids. Obtained results and their reliability are discussed.

LOW COST MISSIONS TO EXPLORE THE DIVERSITY OF NEAR EARTH COMETARY NUCLEI.

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A scientific rationale is presented for undertaking a series of low absolute cost flyby/flythrough missions to near-Earth cometary nuclei. The primary scientific goal is to study the *diversity* in cometary nuclei and builds on the results of VEGA/GIOTTO missions to Halley and the ICE mission to Giacobini-Zinner. It is shown how such a program would naturally complement future "approved" missions like CRAF and ROSETTA. An attempt is made to define a rational concept of diversity for the purpose of mission planning and groups of specific measurement goals are proposed. The concept can easily be extended to an international program in which budgetary and technical interdependencies are minimized but for which scientific productivity is optimized. The mission concept is based on the availability of low cost launchers (Pegasus) and fully integrated spacecraft/instrument development. Mission costs (based on class C/D quality assurance guidelines) are expected to be well below \$100M per mission.

DISTRIBUTION OF ACTIVE AREAS ON THE NUCLEUS OF COMET P/HALLEY: EVIDENCE FOR INHOMOGENEITY.

Michael J.S. Belton, Kitt Peak National Observatory, Tucson AZ 85719, William H. Julian, New Mexico State University, Las Cruces, NM 88003, and Beatrice E.A. Mueller, Kitt Peak National Observatory, Tucson AZ 85719

A new model for the spin state of the nucleus of comet P/Halley (Belton *et al.* 1991, submitted to *Icarus*), which satisfies a wide range of ground-based, earth-orbital, and spacecraft data, is used to explore the distribution of active areas on the surface of comet Halley. The model is an axially symmetric rotator with the shape of a prolate spheroid. The spin vector is inclined to the (fixed) angular momentum vector by 21°.4 and precesses around it with a period of 3.69 days. The total spin period is 2.84 days. Most of the activity seen from the ground is found to originate in five specific locations on the nucleus and one of these regions (located near the waist of the nucleus) appears to have properties that are different from those of the others. In particular there is evidence that it was active at large heliocentric distances (>5 AU) on approach to the Sun. We discuss the possibility that this area represents a large-scale chemical inhomogeneity in the nucleus.

SIMULATED FAMILIES: A TEST OF DIFFERENT METHODS OF FAMILIES IDENTIFICATION

P. Bendjoya (1), A. Cellino (2), Cl. Froeschle' (1), and V. Zappala' (2)

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A set of families generated in fictitious impact events (leading to a wide range of "structures" in the orbital elements space) have been superimposed to various backgrounds of different densities in order to investigate the efficiency and the limitations of the methods by Zappala' *et al.* (Astron.J., 100, 2030, 1990) and Bendjoya *et al.* (Submitted to Astron. and Astrophys., 1991) for identifying asteroid families. In addition, an evaluation of the expected interlopers at different significance levels, the possible apparent splitting of families characterized by very high ejection velocities, the possibility of improving the definition of the level of maximum significance of a given family, etc., were analyzed.

THE USE OF THE WAVELET CLUSTER ANALYSIS FOR ASTEROID FAMILY DETERMINATION.

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Abstract:

The asteroid family determination has been for a longtime analysis method dependent. A new cluster analysis based on the wavelet transform has allowed an automatic definition of families with a degree of significance versus randomness. Actually this method is rather general and can be applied to any kind of structural analysis. We will rather concentrate on the main features of the method. The analysis has been performed on the set of 4100 asteroid proper elements computed by Milani and Knézévic (Celestial Mechanics submitted 1990). Twenty one families have been found and influence of the chosen metric has been tested. The results have been compared with Zappala et al.'s ones (Astronomy and Astrophysics submitted 1990) obtained by the use of a completely different method applied on the same set of data. For the first time, a good overlapping has been found between the both method results, not only for the big well known families but also for the smallest ones.

STOCHASTICITY OF COMET P/SLAUGHTER-BURNHAM; D.Benest and R.Gonczi, O.C.A. Observatoire de Nice

Three comets are now known to be at or near the 1/1 resonance with Jupiter: P/Slaughter-Burnham, P/Boethin and the newly discovered P/Ge-Wang. Although details of the individual orbits differ, the three comets have very similar general dynamical behaviour: their orbits show many transitions between the different types of resonant motion (satellite libration, anti-satellite libration and circulating motion) [1].

The stochastic character of such cometary orbits, mainly due to encounters with Jupiter, is investigated. For each comet of the group, we study the influences of initial eccentricity, inclination, longitude of node and $l - l_J$ (mean longitude of comet minus mean longitude of Jupiter).

We present here our first results for P/Slaughter-Burnham.

Reference:

[1] D.Benest, 1990, *Celest.Mech.* 47,361

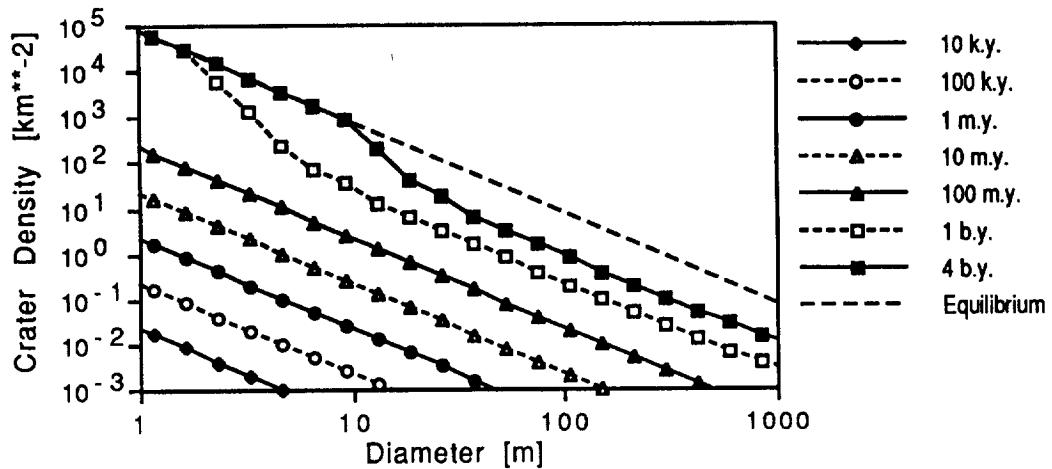
LIFETIME AND CRATERING RECORD FOR GASGRA: A PRE-GALILEO ESTIMATE

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We attempt to quantitatively model the collisional environment and surface evolution of asteroid 951 Gaspra prior to the flyby of the Galileo spacecraft later this year. We compute Gaspra's average intrinsic collisional probability to be $5.4 \times 10^{-18} \text{ km}^{-2} \text{ yr}^{-1}$ with a root mean square impact velocity of 5.0 km sec^{-1} . The impacting population is highly uncertain and we consider three cases for high, intermediate, and low fluxes. Based on these models, Gaspra is unlikely to be a primordial object surviving from the beginning of the solar system. It is most likely a second or multiple generation fragment forming $\sim 10^8 \text{ yr}$ ago. For an age $< 10^9 \text{ yr}$ and a constant intermediate impacting population, we predict Gaspra's surface is not in a state of crater equilibrium. For this case the crater size distribution directly reveals the size distribution of the impacting population. In the figure below we present isochrons assuming an intermediate impactor population as proposed by Greenberg and Chapman (1983, *Icarus* 55, 455). If an equilibrium surface is found, our model sets lower limits for the age ($\sim 10^9 \text{ yr}$) and flux for Gaspra.



TROJAN, HILDA, AND CYBELE ASTEROIDS: ARE THEY *REALLY* MORE ELONGATED THAN MAIN-BELT OBJECTS?

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Previous researchers (French 1987, *Icarus* 72, 325; Hartmann et al. 1988, *Icarus* 73, 487) have proposed that Trojan asteroids (and perhaps Hildas and Cybeles) have higher mean lightcurve amplitudes than their similar-diameter counterparts in the main belt, possibly due to differences in their formation or subsequent collisional evolution. We have obtained new lightcurve observations of 23 Trojan, Hilda, and Cybele asteroids using the University of Texas McDonald Observatory 2.1- and 0.9-m telescopes over the interval 1987-1990. Because this new data set significantly increases the sample size and because many of the newly observed objects display low lightcurve amplitudes, we are performing a new and rigorous analysis to test the higher amplitude hypothesis.

Of particular importance to this new analysis is a correction for bias effects. These arise in at least two ways. First, large amplitude lightcurves are easier to detect and are more likely to lead to publishable and tabulated results. Second, previous analyses have used the tabulated value for the *maximum* observed amplitude. This presents a bias toward higher amplitudes for objects that have been observed over multiple apparitions, as is the case for many Trojans.

We seek to overcome these biases in the following ways. First we include all data, even those that yield no rotation period information and give only a lower limit for the lightcurve amplitude. Second, we apply a geometric correction factor to multiply observed asteroids in order to estimate the lightcurve amplitude which would most likely be observed at a single random polar aspect angle. For randomly oriented spin vectors, this corresponds to an aspect angle of 60 degrees.